

CLAIMS

1. Transmitting apparatus which transmits a data
signal to a receiving apparatus via at least two
5 different transmission paths, comprising:

an antenna array;

a transmitter array connected to the antenna
array; and

10 a plurality of beamformers connected to the
transmitter array, each beam former being operable to
receive a transmission signal and to modify the
transmission signal, such that the antenna array
produces a plurality of directional transmission beams
carrying respective transmission signals which are
15 transmitted via different transmission paths to the
receiving apparatus; and

a space-time encoder which applies space-time
coding to the data signal thereby to produce space-time
encoded transmission signals for transmission by the
20 respective transmission beams.

2. Apparatus according to claim 1 wherein the
space-time encoder means is arranged to transmit an
item of data in different transmission beams at
25 different times.

3. Apparatus according to claim 1 wherein the
space-time encoder is arranged such that a first
transmission signal comprises two sequential symbols
30 and a second transmission signal comprises the two
symbols in reverse order.

4. Apparatus according to claim 3 wherein one of
the symbols in one of the transmission signals is the
35 complex conjugate of the corresponding symbol in the
other transmission signal, and one of the symbols in

one of the transmission signals is the inverse of the complex conjugate of the corresponding symbol in the other transmission signal.

5 5. Receiving apparatus which receives a plurality of transmission signals and outputs a combined signal based on the plurality of transmission signals, comprising:

10 a receiver operable to receive a plurality of transmission signals carried in respective directional transmission beams via respective transmission paths, and to separate the plurality of transmission signals; and

15 a space-time decoder which is operable to decode the transmission signals which have been space-time coded.

20 6. Apparatus according to claim 5 wherein the space-time decoder comprises a channel estimator which estimates channel vectors of the transmission paths, and a combiner which combines the received transmission signals with the channel vectors estimated by the channel estimator to yield an output signal.

25 7. Transmitting apparatus which transmits a data signal to a receiving apparatus via at least two different transmission paths, comprising:

 an antenna array;

30 a transmitter array connected to the antenna array;

 a plurality of beamformers connected to the transmitter array, each beam former being operable to receive a transmission signal and to modify the transmission signal, such that the antenna array
35 produces a plurality of directional transmission beams carrying respective transmission signals which are

transmitted via different transmission paths to the receiving apparatus; and

a plurality of channel encoders, each channel encoder being operable to encode the data signal according to a different channel code, thereby to produce the transmission signals for transmission by the respective transmission beams.

8. Apparatus according to claim 7 wherein the channel encoders are arranged to code the data signals such that cross-correlation between the transmission signals is lower than would be the case if different channel encoding were not employed.

9. Apparatus according to claim 7 wherein the channel encoders are arranged to apply different error protection codes to the transmission signals.

10. Apparatus according to claim 7 wherein the coding applied by the channel encoders is at least one of convolution coding, turbo coding, block coding and interleaving.

11. Receiving apparatus which receives a plurality of transmission signals and outputs a combined signal based on the plurality of transmission signals, comprising:

a receiver operable to receive a plurality of transmission signals carried in respective directional transmission beams via respective transmission paths, and to separate the plurality of transmission signals;

a plurality of channel decoders each of which decodes one of the transmission signals which has been channel encoded differently from the other transmission signals; and

a combiner which combines signals decoded by the

channel decoders to yield the output signal.

12. Apparatus according to claim 11 wherein the channel decoders are arranged to decode signals which have been coded using different error protection codes.

13. Apparatus according to claim 11 wherein the channel decoders are arranged to decode signals which have been coded using at least one of different turbo codes, different convolution codes, different block codes and different interleaving.

14. Transmitting apparatus which transmits a data signal to a receiving apparatus, comprising:

an antenna array;

a transmitter array connected to the antenna array;

a plurality of beam formers connected to the transmitter array, each beam former being operable to receive a transmission signal and to modify the transmission signal, such that the antenna array produces a plurality of directional transmission beams carrying respective transmission signals which are transmitted via different transmission paths to the receiving apparatus;

a receiver operable to receive from the receiving apparatus a feedback signal indicating a quality of the transmission beams; and

a processor programmed to select at least one of the plurality of transmission beams based on the feedback signal and to insert the data signal only in those transmission signals which correspond to the selected transmission beams.

15. Apparatus according to claim 14 wherein the processor is programmed to determine whether the

transmission beams have faded and to select transmission beams which are not faded.

5 16. Apparatus according to claim 15 wherein the processor is programmed to select transmission beams additionally based on the relative powers of the transmission beams.

10 17. Apparatus according to claim 15 wherein the processor is programmed to select transmission beams additionally based on the directions of the transmission beams.

15 18. Apparatus according to claim 14 wherein the processor is programmed to transmit a control signal in a transmission beam which is not selected, which control signal is for use in measuring the quality of the transmission beam.

20 19. Apparatus according to claim 14 wherein the feedback signal comprises a number of feedback symbols equal to the number transmission beams, and each feedback symbol indicates whether one of the transmission beams has faded.

25 20. Apparatus according to claim 14 wherein the feedback signal comprises measures of the quality of each of the transmission beams.

30 21. Apparatus according to claim 20 wherein the receiver is arranged to receive the quality measures for different transmission beams at different times on a predetermined time division multiplexing basis.

35 22. Apparatus according to claim 14 wherein the processor is programmed to alter signals to be carried

by the transmission beams such that the transmission beams are distinguishable from each other.

23. Transmitting apparatus which transmits a plurality of transmission signals, comprising:

an antenna array;

a transmitter array connected to the antenna array;

a plurality of beam formers connected to the transmitter array, each beam former being operable to receive a transmission signal and to modify the transmission signal, such that the antenna array produces a plurality of directional transmission beams carrying respective transmission signals; and

a processor programmed to adjust the relative timing of at least two transmission signals such that, when the corresponding transmission beams are received at a receiving apparatus via different transmission paths the two transmission signals are substantially in time synchronism.

24. Apparatus according to claim 23 wherein the processor is programmed to adjust the relative timing of the two transmission signals in dependence on a measure of the relative propagation delay of the corresponding transmission paths.

25. Apparatus according to claim 24 wherein the processor is programmed to measuring the relative propagation delay of the transmission paths.

26. Apparatus according to claim 24 wherein the processor is programmed to receive the measure of the relative propagation delay from the receiving apparatus.

27. Apparatus according to claim 23 wherein the two transmission signals both comprise a signal to be transmitted to the receiving apparatus.

5 28. Apparatus according to claim 23 wherein one transmission signal comprises a signal to be transmitted to the receiving apparatus and the other transmission signal comprises a signal to be transmitted to a different receiving apparatus.

10 29. Apparatus according to claim 23 wherein the processor is programmed to select transmission signals which are to have their relative timing adjusted based on the directions of the corresponding transmission
15 beams.

20 30. Apparatus according to claim 23 wherein the processor is programmed to select transmission signals which are to have their relative timing adjusted based on the relative powers of the corresponding transmission beams.

25 31. Apparatus according to claim 23 further comprising two orthogonal coders which apply at least one of orthogonal spreading codes and orthogonal scrambling codes to the two transmission signals.

32. Receiving apparatus which receives signals transmitted by a transmitting apparatus, comprising:

30 a receiver which receives a plurality of directional transmission beams transmitted from the transmitting apparatus via different transmission paths, each transmission beam carrying a transmission signal;

35 a processor programmed to measure a relative propagation delay of the transmission signals and to

produce a feedback signal based on a measure of the relative propagation delay; and

a transmitter which transmits the feedback signal from the receiving apparatus to the transmitting apparatus.

33. Transmitting apparatus for transmitting a data signal to a receiving apparatus via at least two different transmission paths, comprising:

space-time encoding means for applying space-time encoding to the data signal thereby to produce a plurality of space-time encoded transmission signals; and

transmitting means for transmitting the plurality of space-time encoded transmission signals to the receiving apparatus via different transmission paths in respective directional transmission beams.

34. Receiving apparatus for receiving a plurality of space-time encoded transmission signals and outputting a combined signal based on the plurality of transmission signals, comprising:

receiving means for receiving the plurality of transmission signals carried in respective directional transmission beams via respective transmission paths; and

decoding means for space-time decoding the plurality of transmission signals which have been space-time encoded.

35. Transmitting apparatus for transmitting a data signal to a receiving apparatus via at least two different transmission paths, comprising:

channel encoding means for encoding the data signal according to a plurality of different channel codes, thereby to produce a plurality of transmission

signals each comprising the data signal encoded according to a different channel code; and

transmitting means for transmitting the plurality of transmission signals to the receiving apparatus via different transmission paths in respective directional transmission beams.

36. Receiving apparatus for receiving a plurality of transmission signals and outputting a data signal based on the plurality of transmission signals, comprising:

receiving means for receiving the plurality of transmission signals carried in respective directional transmission beams via respective transmission paths;

decoding means for decoding the transmission signals, each of the transmission signals having been encoded according to a different channel code; and

combining means for combining signals decoded by the decoding means to yield the data signal.

37. Transmitting apparatus for transmitting a data signal to a receiving apparatus, comprising:

transmitting means for transmitting a plurality of directional transmission beams to the receiving apparatus via different transmission paths;

receiving means for receiving from the receiving apparatus a feedback signal indicating a quality of the transmission beams; and

selecting means for selecting at least one of the plurality of transmission beams based on the feedback signal;

wherein transmitting means is arranged to transmit the data signal only in those transmission beams selected by the selecting means.

38. Transmitting apparatus for transmitting a

plurality of transmission signals, comprising:

transmitting means for transmitting a plurality of directional transmission beams, each transmission beam carrying a transmission signal; and

5 time adjusting means for adjusting the relative timing of at least two transmission signals such that, when the corresponding transmission beams are received at a receiving apparatus via different transmission paths the two transmission signals are substantially in
10 time synchronism.

39. Receiving apparatus for receiving signals transmitted by a transmitting apparatus, comprising:

15 receiving means for receiving a plurality of directional transmission beams transmitted from the transmitting apparatus via different transmission paths, each transmission beam carrying a transmission signal;

20 means for measuring a relative propagation delay of the transmission signals;

 means for producing a feedback signal based on a measure of the relative propagation delay; and

 means for transmitting the feedback signal from the receiving apparatus to the transmitting apparatus.

25 40. A method of transmitting a data signal from a transmitting apparatus to a receiving apparatus via at least two different transmission paths, comprising:

30 applying space-time encoding to the data signal thereby to produce a plurality of space-time encoded transmission signals; and

35 transmitting the plurality of space-time encoded transmission signals to the receiving apparatus via different transmission paths in respective directional transmission beams.

41. A method of receiving a plurality of space-time encoded transmission signals and outputting a combined signal based on the plurality of transmission signals, comprising:

5 receiving the plurality of transmission signals carried in respective directional transmission beams via respective transmission paths; and

space-time decoding the plurality of transmission signals which have been space-time encoded.

10 42. A method of transmitting a data signal from a transmitting apparatus to a receiving apparatus via at least two different transmission paths, comprising:

15 encoding the data signal according to a plurality of different channel codes, thereby to produce a plurality of transmission signals each comprising a data signal encoded according to a different channel code; and

20 transmitting the plurality of transmission signals to the receiving apparatus via different transmission paths in respective directional transmission beams.

25 43. A method of receiving a plurality of transmission signals and outputting a data signal based on the plurality of transmission signals, comprising:

receiving the plurality of transmission signals carried in respective directional transmission beams via respective transmission paths;

30 decoding the transmission signals, each of the transmission signals having been encoded according to a different channel code; and

combining the thus decoded signals to yield the data signal.

35 44. A method of transmitting a data signal from a transmitting apparatus to a receiving apparatus,

comprising:

transmitting a plurality of directional
transmission beams from the transmitting apparatus to
the receiving apparatus via different transmission
5 paths;

receiving the plurality of directional
transmission beams;

producing measures of a quality of the
transmission beams;

10 producing a feedback signal based on the measures
of the quality of the transmission beams;

transmitting the feedback signal from the
receiving apparatus to the transmitting apparatus;

receiving the feedback signal;

15 selecting at least one of the plurality of
transmission beams based on the feedback signal; and

transmitting the data signal only in the selected
transmission beams.

20 45. A method of transmitting a plurality of
transmission signals, comprising:

adjusting the relative timing of at least two
transmission signals; and

25 transmitting a plurality of directional
transmission beams, each transmission beam carrying a
transmission signal;

30 wherein the relative timing of the at least two
transmission signals is adjusted such that, when the
corresponding transmission beams are received at a
receiving apparatus via different transmission paths
the two transmission signals are substantially in time
synchronism.